Center for Night Vision and Electro-Optics

AMSEL-NV-TR-0064

DEVELOPMENT AND MANUFACTURE OF THE MICROCHANNEL PLATE (MCP)

by
Walter B. Morrow, Jr., John Rennie, and William Markey

February 1988

Approved for public release; distribution unlimited.

FORT BELVOIR, VIRGINIA 22060-5677

AMSEL-RD-NV-D (DTIC-HAC/9 Jun 88) (702-3b) 1st End
SUBJECT: Technology Screening of Unclassified/Unlimited Reports (CNVEO Rept. AMSEL-NV-TR-0064)

Headquarters, US Army Communications-Electronics Command, Center for Night Vision and Electro-Optics, ATTN: AMSEL-RD-NV-D, Fort Belvoir, VA 22060-5677

FOR: Defense Logistics Agency, Defense Technical Information Center, ATTN: DTIC-HAS, Cameron Station, Alexandria, VA 22304-6145

1. CNVEO has reviewed the report cited in the referenced letter and the cited MCTL References paragraphs 4.1.3(4d) and 7.3.3. In addition CNVEO has reviewed the issue with the PMO-NVD and Varian Associates.

2. The MCTL (Oct 1986) sets forth as militarily critical technology three items which are relevant to the CNVEO Report AMSEL-NV-TR-0064. These items are a. (U) Chemical Processing of the Multiple Fibre Wafer; b. (U) Hydrogen Firing and Vacuum Bake of the Multiple Fibre Waver; and c. (U) Deposition of Ion Barrier Films less than or equal to 50 nanometers in thickness. The subject CNVEO report consists of two main sections, the first being a very much simplified and qualitative outline of the general type of steps required to manufacture a microchannel plate. These steps are generic and gleened from 1967-1971 vintage material which has been in the public domain since that time. Ion Barrier Films are mentioned only to state without embellishment, the generally known fact that such films may be applied to an otherwise finished microchannel plate. Microchannel plates are currently manufactured by British, French, and Dutch interests and to some extent in the Eastern Block. The material is also wholly lacking in all the critical information such as chemical composition, temperatures, times/schedules, degree of vacuum or pressure etc., without which the process cannot be accomplished. The second part of the report consists of a reproduction of a Varian Associates Pamphlet MCP-2819B which is a commercial marketing type pamphlet published initially in 1975 with at least three subsequent reprintings. It deals only with typical performance parameters. Similar or identical material to that published in the CNVEO report has appeared in standard technical books and has been the subject of many professional/technical papers presented around the world. Some 20,000 copies of the Varian pamphlet itself have been printed and distributed world wide.

AMSEL-RD-NV-D
SUBJECT: Technology Screening of Unclassified/Unlimited Reports (CNVEO Report AMSEL-NV-TR-0064)

3. Based upon the above it is the considered opinion of CNVEO that there exists no basis for changing the "unclassified/unlimited" classification of the subject report. This report has been intended by CNVEO to provide a simplistic tutorial for those who become or may become involved in the area of night vision systems, who are not necessarily engineers or scientists, yet who require some basic understanding of the technologies involved. The dedicated technologist can readily pursue the subject to much greater depth in the published literature.

4. Questions on the above should be directed to Mr. Walter B. Morrow, Deputy Director Technical Support Division on AUTOVON 354-5694 or Commercial 664-5694.

RUDOLF G. BUSER
Acting Director
CNVEO

DEPARTMENT OF THE ARMY
CENTER FOR NIGHT VISION AND ELECTRO-OPTICS
FORT BELVOIR, VIRGINIA 22060-5677
AMSEL-~~RD~~-NV-TS
OFFICIAL BUSINESS
PENALTY FOR PRIVATE USE. $300

Defense Logistics Agency
Defense Technical Information Center
ATTN: DTIC-HAS
Cameron Station
Alexandria, VA 22304-5677

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

1a. REPORT SECURITY CLASSIFICATION Unclassified	1b. RESTRICTIVE MARKINGS None
2a. SECURITY CLASSIFICATION AUTHORITY	3. DISTRIBUTION/AVAILABILITY OF REPORT Approved for public release; unlimited distribution.
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE	
4. PERFORMING ORGANIZATION REPORT NUMBER(S) AMSEL-NV-TR-0064	5. MONITORING ORGANIZATION REPORT NUMBER(S)
6a. NAME OF PERFORMING ORGANIZATION Center for Night Vision and Electro-Optics (CNVEO) 6b. OFFICE SYMBOL (If applicable) AMSEL-RD-NV-TS	7a. NAME OF MONITORING ORGANIZATION
6c. ADDRESS (City, State, and ZIP Code) Fort Belvoir, VA 22060-5677	7b. ADDRESS (City, State, and ZIP Code)
8a. NAME OF FUNDING/SPONSORING ORGANIZATION 8b. OFFICE SYMBOL (If applicable)	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER
8c. ADDRESS (City, State, and ZIP Code)	10. SOURCE OF FUNDING NUMBERS PROGRAM ELEMENT NO. | PROJECT NO. | TASK NO. | WORK UNIT ACCESSION NO.

11. TITLE (Include Security Classification)

DEVELOPMENT AND MANUFACTURE OF THE MICROCHANNEL PLATE (MCP) (U)

12. PERSONAL AUTHOR(S)

Walter B. Morrow, Jr., John Rennie, William Markey

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (Year, Month, Day)	15. PAGE COUNT
Final	FROM 1962 TO 1988	February 1988	29

16. SUPPLEMENTARY NOTATION

17. COSATI CODES			18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
FIELD	GROUP	SUB-GROUP	IMAGE INTESIFIERS(ELECTRONICS) cladding glass; etched core approach; boule fusion; chemical etching; hydrogen firing; image intensifier tube; electron scrub; ~~GaAs~~ Gallium ARSENIDE. (JES)

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

This technical report contains an overview of the development and production of a critical night vision electronic device, the microchannel multiplier or microchannel plate (MCP). Technological challenges and manufacturing processes for the second and third generation image intensifier tube systems are outlined including materials selection, thermo-mechanical processing, chemical processing, mechanical processing and assembly, and cleaning, chemical activation, and electron scrub. Also contained in this report are three figures which chart MCP research and development investment/payoff, unit cost reduction curve for second generation, and estimated production cost comparisons of years 1977 and 1987. The Appendix contains Varian Associates' pamphlet MCP-2819B, *Applications for Microchannel Plates*. (Kay words)

20. DISTRIBUTION/AVAILABILITY OF ABSTRACT ☐ UNCLASSIFIED/UNLIMITED ☒ SAME AS RPT. ☐ DTIC USERS	21. ABSTRACT SECURITY CLASSIFICATION Unclassified
22a. NAME OF RESPONSIBLE INDIVIDUAL Walter B. Morrow	22b. TELEPHONE (Include Area Code) 703/664-5694 | 22c. OFFICE SYMBOL AMSEL-RD-NV-TS

DD Form 1473, JUN 86 — Previous editions are obsolete. — SECURITY CLASSIFICATION OF THIS PAGE

Unclassified

PREFACE

This report provides a brief overview of the development of the microchannel electron multiplier or microchannel plate (MCP) with emphasis on the technological challenges to produce this critical device. The MCP is one of the most physically complex electronic devices in mass production today and is the critical component enabling the Army to deploy more than 150,000 low cost night vision systems. Applications span all of the military services and include man-carried, combat vehicle and aviation applications, both fixed and rotary wing. Emphasis is also placed on the need for well structured, fully supported, and funded developmental programs where technological challenges and barriers are overcome systematically, thus achieving the desired goals of full performance, low cost production, and high reliability with attendant low operational and sustaining cost.

The Appendix contains Varian Associates, Light Sensing and Emitting Division, Palo Alto, CA, pamphlet #MCP-2819B, *Applications for Microchannel Plates.*

TABLE OF CONTENTS

SECTION I. INTRODUCTION

By mid year 1987, the US Army procured and deployed more than 150,000 second generation image intensifier systems. These include the AN/PVS-4 small starlight scope, AN/TVS-5 crew served weapon sight, AN/PVS-5 night vision goggles, and third generation high performance AN/AVS-6 aviation night vision goggles. By 1990, more than 300,000 such systems are expected to be deployed to Army, Air Force, Navy, and Marine Corps units worldwide. These systems are all characterized by significantly smaller size, lighter weight, higher performance, and lower cost than their first and zero generation counterparts. The very popular goggles were in fact not technologically possible in first and zero generation. The unique device which has made this possible is the continuous channel electron multiplier, better known as the Microchannel Plate (MCP). The MCP development was supported by a long range commitment by the Army to research and investment in the technology during the years 1962-1985. Prototype image tubes fabricated in the early 1970s had MCPs costing several thousand dollars. Today, high performance MCPs cost less than $200 each in quantity (refer to Section III). This was accomplished over a decade and a half in which the aggregate inflation was nearly 300%. Low cost efficient mass production of MCPs is something of a technological miracle considering the lengthy and complex process.

There are a number of lessons to be learned from the Army's program for second generation image tube and MCP development. These include, as a minimum, the following:

- Key component development continued throughout the development cycle for end item hardware.

- Detailed specifications were generated for both MCPs and tubes and were evaluated in-house against these specifications.

- Simulated test apparatus were designed, fabricated, and tested in-house as vehicles to check contractor performance and recommend positive changes. In fact, the Center for Night Vision and Electro-Optics (CNVEO), through intense in-house research, was often in the forefront and transferred vital data, particulary processing methods, to industry.

- Attempts at accelerated development did not succeed schedule wise, indicating that the application of brute force cannot be substituted for sound scientific methodology.

- The worldwide deployment of thousands of low cost second and third generation image intensifier systems was the result of a logical and well thought out effort, Advanced

Development, Engineering Development, pre-production preparation manufacturing, materials, and technology programs (MM&Ts), facility contracts, and a plan to insure a healthy degree of legitimate competition, i.e., Educational Buys and Qualified Sources for critical items/components.

SECTION II. MCP DEVELOPMENT AND MANUFACTURING CHALLENGES

The concept of a continous channel electron multiplier was developed near the end of 1950. The invention was that of G.W. Goodrich of the Research Laboratories Division, Bendix Corporation. The intrinsic property of glass as a defacto amorphous super-cooled fluid subject to tensile creep at relatively low temperatures lent itself readily to the development of the MCP as we know it today. Early experiments with brittle insulators such as polycrystalline isotropic ceramics were never successful for this application. Even with glass, several approaches were explored. The principal approaches were the hollow core and etched core MCPs. The hollow core approach, while viable in principal, has never achieved economically satisfactory manufacturing yields. Thus today, only the etched core approach remains. An understanding of the challenges to be overcome in the development and manufacture of the modern MCP can best be done in the context of the manufacturing process itself; therefore, the more significant steps in that process are reviewed. In general, the technological challenges have been in materials selection, thermo-mechanical processing, chemical processing (etching, hydrogen firing), mechanical processing and assembly, and finally, cleaning, chemical activation, and electron scrub.

Selection of core and cladding glass material is the first challenge. The cladding glass must be a high lead concentration glass which can be hydrogen fired to produce a conductive layer on the inside of the tube. Approaches which would attempt to apply a conductive coating directly to the inside of channels were infeasible due to the small channel diameter (8-9 microns) which was ultimately required. The core glass must match the thermal expansion coefficient of the cladding glass; otherwise, the two could not be processed at temperature. A mismatch prevents the fusion of core and cladding glass and results in improper preparation of the cladding glass surface and fracturing of the cladding glass itself. Finally, the core glass must be subject to etching while the cladding glass must remain impervious to the etching material. After much research, it was determined that the ideal cladding glass was Corning 8161, containing a high concentration of lead and requiring rubidium as a catalyst in the manufacturing process. However, Corning's supply of this glass was limited and access to rubidium was severly limited by a trade embargo against Rhodesia, the principal supplier. This forced the industry to seek alternative ways of producing the 8161 glass or develop an equivalent. This was accomplished through an intense and structured effort by the CNVEO through in-house research and contracts for material research, manufacture of the test MCPs, and testing in image tube structures. The problem was fully resolved in just 18 months.

The next three steps are drawing and stacking steps in which initially the core and cladding glass are concentrically drawn to a very thin diameter. Both glasses must have the same temperature/flow characteristics. In the first step, single glass rods are drawn down to a specified diameter. In the second step, the singles are stacked and fused. This requires careful temperature control to affect uniform fusion without inducing excess flow or geometric distortion. Finally, the third step is the multi-draw step requiring precision temperature control and very exact control of the tensile load applied to effect the draw. The result of these three steps is to obtain a center-to-center spacing between channels of 12 microns and individual channel diameters of 8-9 microns uniform over an effective plate area of 18-25 millimeters.

The next step requires mechanical assembly of drawn multibundles into a solid rim followed by pressing and fusing into a boule. Boule fusion is critically dependent upon process time and timing, and precise control of both pressure and temperature. Because of the intrinsic flow/creep properties of glass, this step, if not precise, can lead to excessive flow, nonuniform fusion, and geometric distortion in the boule. The ability to do this relates in no small way to the intrinsic uniformity of the glass tubing used at the start of the process.

Having fabricated a successful glass boule, it is now necessary to slice the boule transversly or nearly so at a small bias angle in the order of 5 to 8° and with a resulting plate thickness of just over 20 mils (.020 inch) allowing for subsequent grinding and polishing. The thickness determines the electron gain/saturation characteristic of the MCP and so these steps must be precise. While the boule itself is robust, the single MCP wafer is mechanically delicate and easily destroyed in these steps. The grinding and polishing step, though outwardly simple for solid glass, is a delicate process here, since it is necessary to prevent smearing of cladding glass into the core glass. Failure here can result in the loss of the plate or produce defective channels in subsequent steps.

At the next stage, chemical etching occurs to remove the core glass and leave open channels. The etch must be controlled since this process not only removes the core glass, but treats the surface of the cladding glass/core glass fusion boundary to produce a secondary electron emission surface with the necessary properties. At the same time, it is critical that all core glass residues and etching materials be removed; otherwise, blocked and defective channels will occur having very undesirable properties.

Having successfully etched and cleaned the MCP, hydrogen firing is next. This serves to reduce the Lead Oxide (PbO) distributed on the inner surface of each channel to conductive metallic lead. The degree of lead oxide reduction obtained determines the conductivity of the inner surface, and the stability of this parameter is a critical function of the time and temperature profiles used in hydrogen firing.

The MCP now passes through the step where electrical contacts are vacuum vapor deposited across the front and back surface areas. The adherence of the contact film is dependent upon the quality and effectiveness of the cleaning, etching, and firing steps in the previous paragraphs. In addition, the choice of electrode material is critical in that thermo-mechanical properties must again be matched in order to insure long term operational stability. The evaporation technique itself is a complex process requiring careful control obtainable only through fully automated processes.

NOTE: Various tests are performed at numerous times during the entire process. Often these tests, like the processes themselves, require exacting and unique jigs, fixturing, control mechanisms, and analytical aids.

The next step in the process is typical of the many requiring special jigs and fixtures. This is the assembly of the MCP into an image intensifier tube body. Special assembly techniques are required and ultra-clean facilities are used continuously. It is critical here that MCP electrodes and tube body electrodes meet and match, guaranteeing electrical contact. Failure here can impact tube gain, noise/background characteristics, and loss of stability due to field emission and arcing/corona effects.

In the final step of the second generation type tube, the MCP is outgassed while in the tube. This is accomplished by a very precisely controlled electron scrub. This has been one of the most challenging areas in MCP development and literally thousands of scrub process schedules have been tested and discarded before achieving the necessary design to produce an optimum mix of MCP electron gain level and stability without producing performance degradation in either the MCP itself or the tube photocathode. Failure in key predecessor steps can, in fact, render this last step essentially impossible of achievement. With the preceeding steps, the basic MCP is completed and installed on an operating image tube of the second generation type.

For third generation tubes, i.e., those having Gallium Arsenide (GaAs) type, MCPs will undergo further processing to add an ion barrier film such as Magnesium Oxide (MgO) onto the input side of the plate. This is done to protect the more sensitive GaAs cathode from ion bombardment generated in the electron multiplication process. Some MCPs are also funnelled; i.e., the input side of the microchannels is widened to increase the effective target area for incident electrons and thus increase the signal-to-noise characteristic and electron collection efficiency of the plate. This step is performed and completed before the basic MCP processing is completed.

SECTION III. SUMMARY OF MCP FABRICATION

Fiber and Boule Process

1. Preparation of core glass - solid glass rod.

2. Preparation of channel clad glass - heavy wall glass tubing.

3. Clad/core assembly - rod inserted into glass tube.

4. Single fiber draw - clad/core assembly reduced in size by approximately 1/50 original dimension.

5. Singled fibers stacked into multiple mold - approximately 2,500 fibers in hexagonal pack.

6. Multiple pack - mechanical retention of pack.

7. Multiple draw - pack reduced in size by approximately 1/50 original dimension.

8. Stacking multiple fibers into a boule - final assembly of fibers that have been reduced in size.

9. Boule press - mechanical retention of reduced fibers.

10. Solid press - glass sleeve which later becomes solid rim of MCP (may be part of boule press).

11. Boule rounding - final outer diameter (OD) dimension.

12. Boule slicing - approximately 100 wafers with a bias angle sliced from boule.

Optical Finishing

13. Wafer rounding - change elliptical configuration (caused by bias angle slice) into a round configuration.

14. Wafer bevelling - reduce sharp edges on periphery.

15. Grind wafer surface - eliminate kerf marks caused by saw.

16. Wafer cleaning - prepare for final polishing.

17. Wafer polishing - optical surface finish.

Chemical Process

18. Standard core etch - removal of core glass.

19. Funnelling etch - optical process used to increase open-area-ration (OAR).

20. Chemical treatment - channel surface preparation.

21. Final cleaning - removal of particulate matter resulting from above processes.

22. Hydrogen reduction - change glass wafer into a semiconductor device with surface conductivity.

23. Electroding - evaporate conductive material on input and output surfaces of the MCP.

Final Test and Inspection

24. Pre-test inspection - detailed visual examination.

25. Electrical test - electronic and electro-optical evaluation of the MCP.

26. Final quality assurance (QA) - quality conformance determination.

NOTES:

- Only major processing steps have been identified. Important intermediate steps have been left out in order to present a concise summary.

- QA inspection centers throughout the fabrication process have not been identified.

- The above summary is germane to the etched core method. However, the hollow drawn method is a parallel type of process.

- Specific details may vary with each MCP manufacturer but the overall summary is valid for all.

- Fiber and Boule Process and Optical Finishing are analogous to fiber optic manufacturing methods.

SECTION IV. INVESTMENT/PAYOFF CONSIDERATIONS

Figure 1 displays the accumulated investment in MCP research and development and the associated unit cost reduction curve for MCPs. Figure 2 shows the unit cost reduction curve for second generation image intensifiers. Figure 3 gives a detailed comparison of estimated production costs in 1977 and 1987. Costs are shown in "then year" inflated dollars except for the bottom line total which is shown in both then year inflated and in FY88 constant dollars. Figure 3 best illustrates the impact of inflation and the substantial cost reduction which has occurred in spite of inflation.

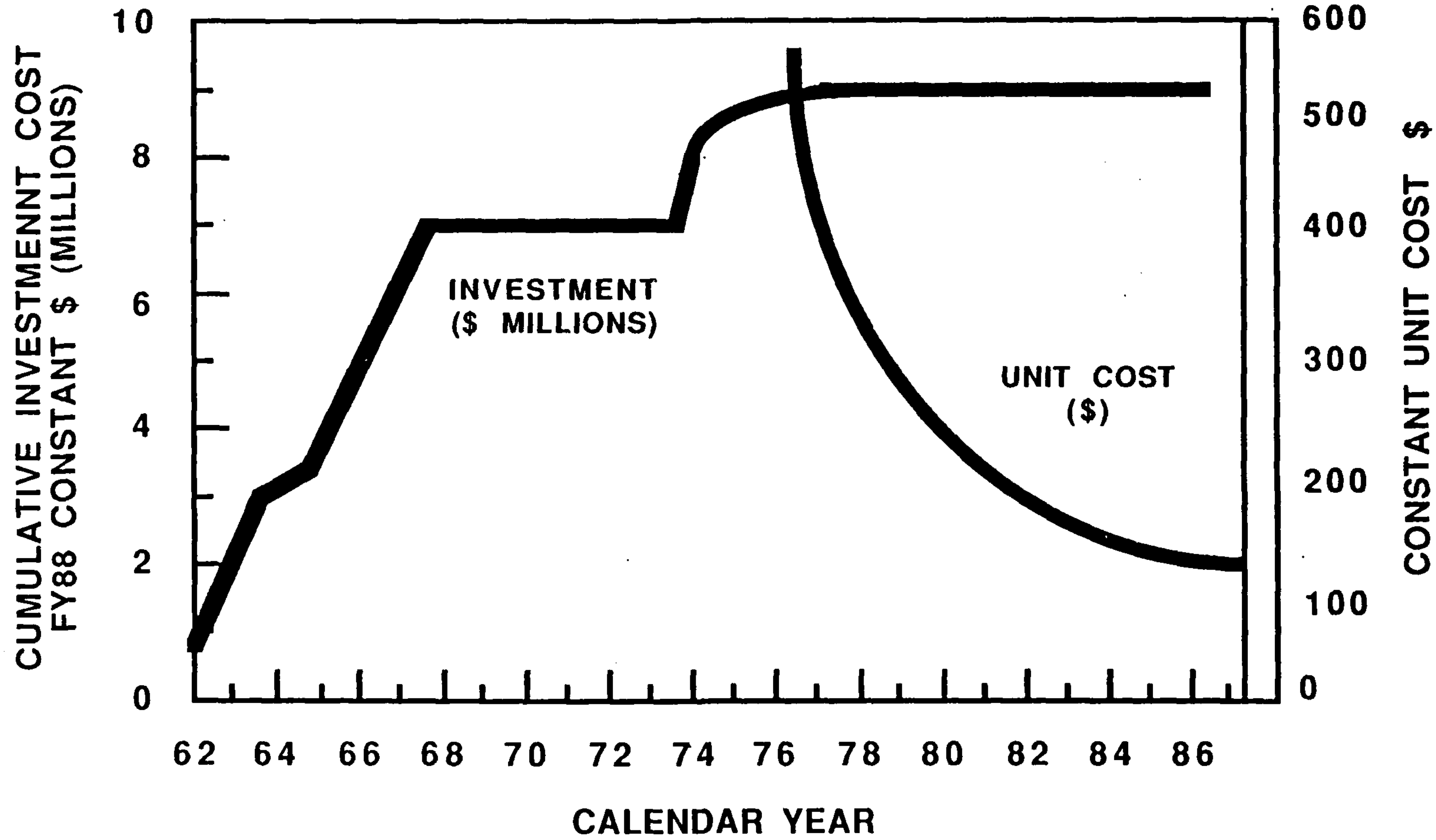


Figure 1. MCP Investment/Payoff

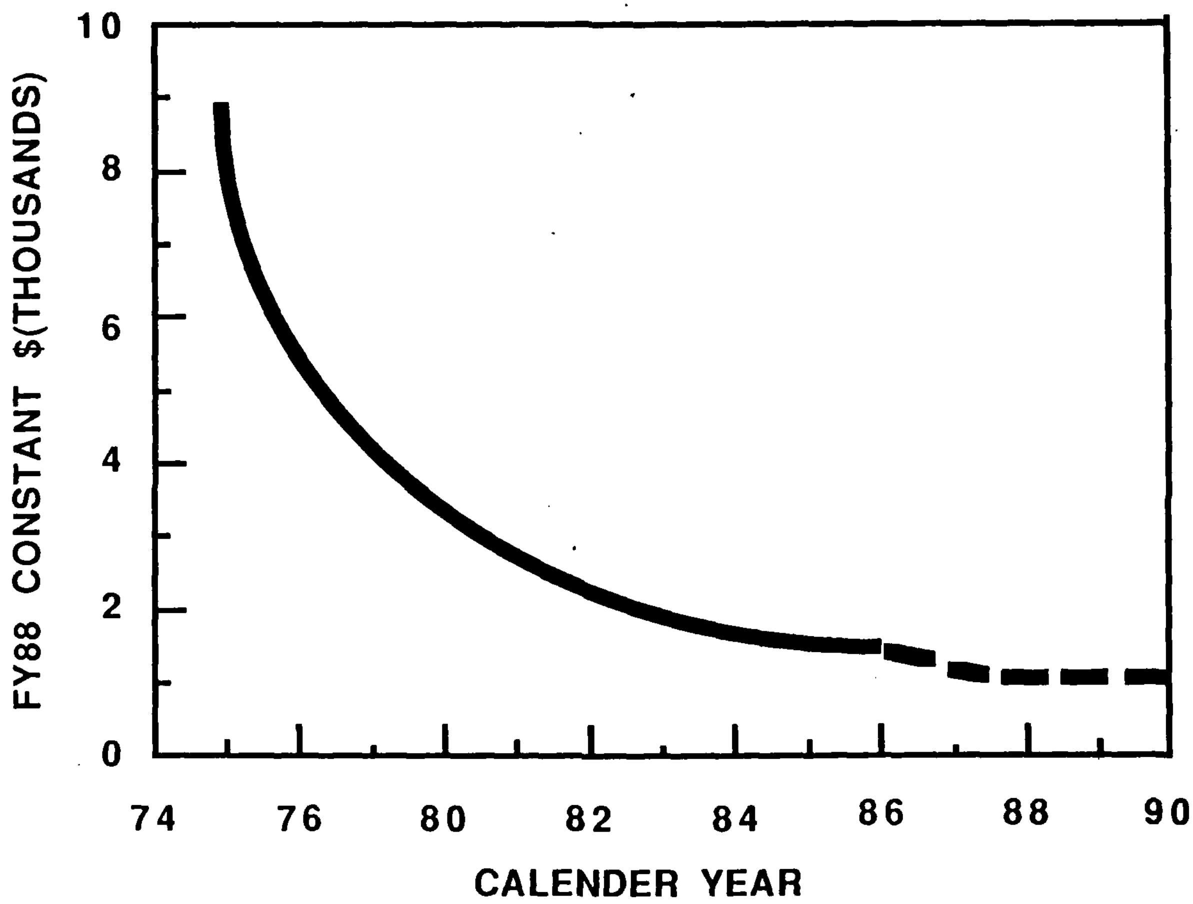


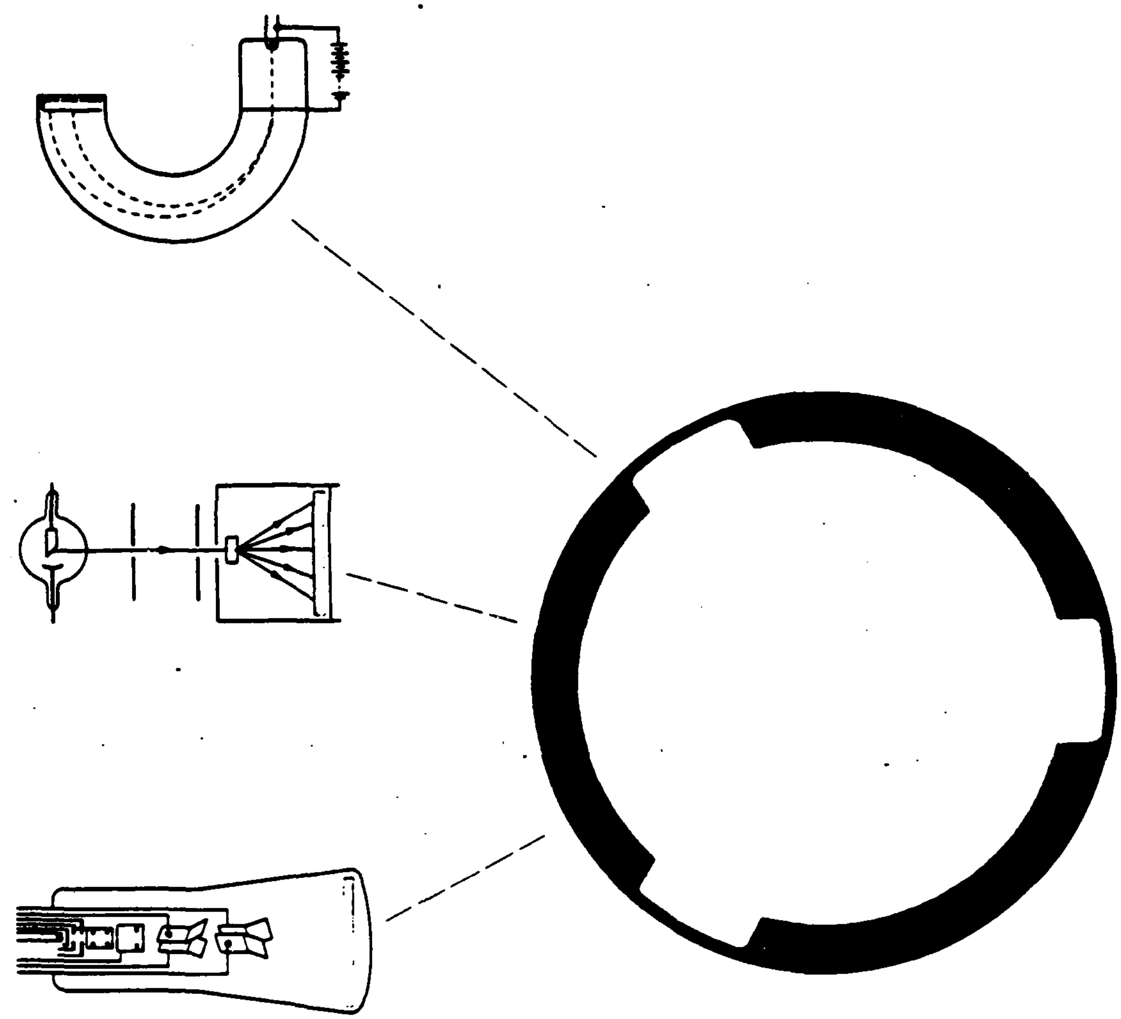
Figure 2. Cost of Second Generation Image Intensifier Tube

Direct Manufacturing Labor	**1977**	**1987**
Fiber and Boule Press	2.5	0.5
Optical Finishing	2.5	0.5
Chemical Process	2.0	0.5
Final Test/Inspection	1.5	0.6
Total Labor Hours/MCP	8.5	2.0
Materials		
Clad Glass	\$ 2.00 (.10lb@\$20/lb)	\$2.00 (.04lb@\$50/lb)core
Glass	\$12.00 (.15lb@\$80/lb)	\$6.00 (.06lb@\$103/lb)
Miscellaneous	\$ 2.00	\$2.00
Cost		
Direct Manufacturing Labor	\$ 42.50 (@\$5/hr)	\$ 24.00 (@\$12/hr)
Manufacturing Overhead (300%)	\$127.50	\$ 72.00
Materials	\$ 16.00	\$ 10.00
Subtotal	\$186.00	\$106.00
G & A (25%)	\$ 46.50	\$ 26.50
Subtotal	\$232.50	\$132.50
Profit (10%)	\$ 23.25	\$ 13.25
TOTAL PRICE	\$255.75 (1977\$)	\$145.75 (1987\$)
	\$462.00 (FY78)	\$151.00 (FY88)

NOTE: Approximately 180,000 MCPs (18-25mm) produced from 1977-1984.

Figure 3. 18mm MCP Manufacturing Costs

APPENDIX A



APPLICATIONS for MICROCHANNEL PLATES

varian

GENERAL INFORMATION

The microchannel plate (MCP) is a disc-shaped, continuous dynode electron multiplier. Single electrons impinging on the input of the MCP are multiplied thousands of times through the process of cascaded secondary emission.

The MCP consists of millions of microscopic hollow-glass conducting channels fused into a disc-shaped array. Since each microscopic channel represents a separate high gain electron multiplier, and perfect position registration exists between the input and output faces of the MCP for each channel, the MCP is ideally suited as an imaging electron multiplier.

A disc, equivalent to the diameter of a quarter, contains approximately 1,760,000 channels of the size used in the type VUW-8900 Series multipliers, and 60% of this disc would be open channels. Since the channels are normally 45 times as long as their diameter, this disc (the diameter of a quarter) would be one-third the thickness of a quarter.

The features of the MCP are:

- **High electron gain**
- **High spatial resolution**
- **Small size**
- **Ruggedness**
- **Low power consumption**
- **Self-saturating**
- **High speed**
- **Low noise**

The features of the MCP offer many advantages over previous discrete dynode type of electron multipliers, primarily due to its size and imaging characteristics, as well as its self-saturating, high speed and low noise capabilities.

In addition to the MCP's ability to detect and amplify electrons, it is also sensitive to various other types of radiation. The microchannel plate should find many industrial and scientific uses in the detection and amplification of:

- Electrons
- Positive ions
- Soft X-rays
- Ultraviolet radiation

Due to the above features, the microchannel plate should offer improved performance over the present state-of-the-art in military, industrial, commercial and scientific applications, such as:

- Night surveillance
- Night warfare image intensifiers
- Low light level television
- Low light level photography
- High speed oscilloscopes
- Electron spectrometers for chemical analysis
- Field ion microscopes
- Electron microscopes
- Soft X-ray detectors and scanners
- Non-destructive testing
- Astronomy
- High speed photomultiplier tubes
- Cathode ray tubes - high brightness
- Cathode ray tubes - miniature, low power
- Quantuum detectors
- Ultraviolet imaging
- Ultra-fast storage tubes

BACKGROUND

Varian Associates has been in the field of continuous channel electron multiplier arrays since early 1967, and is the largest supplier of these devices in the United States, having supplied over 80% of the military requirements for microchannel plates for use in night vision devices since 1969. We have one of the finest Production, Engineering and Development teams available to develop and produce channel multiplier devices to customer specifications.

Until June 1971, the MCP was classified "Confidential" by the U.S. Department of Defense, but is now unclassified. Because of its prior classification, the major application of the MCP until recently has been in military second generation direct-view night vision systems, such as:

- Night vision goggles
- Crew-served weapon sight
- Small starlight scope

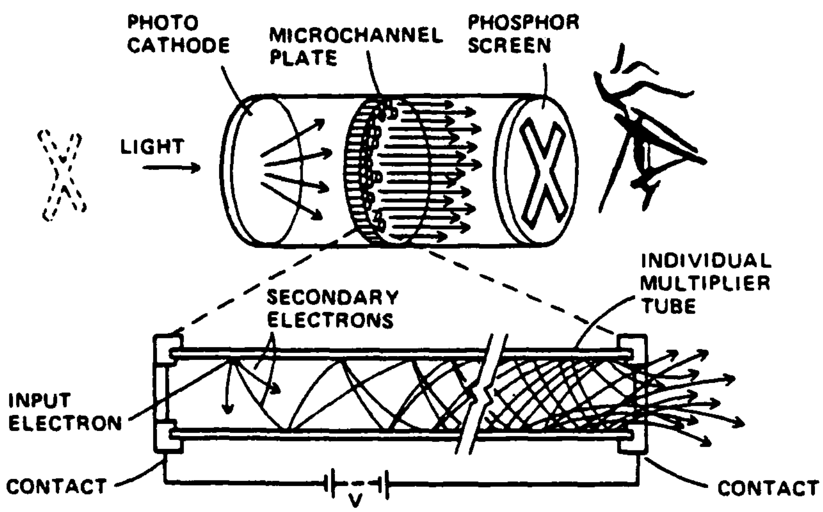
Future military systems which offer potential applications are:

- Tank periscopes
- Night vision aerial periscopes
- Night rescue helicopter missions
- Continuing army direct-view night vision scopes and goggles

Future uses of the MCP in non-military devices are multiform and various, and are discussed in a subsequent section on Applications.

PRINCIPLE OF OPERATION

The glass channels in the MCP, are connected in parallel electrically by metal electrodes on opposite faces of the disc. The MCP, which must operate in a vacuum, is specially processed to produce secondary electrons from the channel surfaces. When radiation impinges on the input of the array, secondary electrons are generated. These secondary electrons are accelerated when voltage is applied between the disc faces. Secondary electrons passing along the channels, collide with the channel surfaces to dislodge additional secondary electrons, thereby producing electron multiplication, or amplification. By varying the voltage across the disc, the gain of the multiplier can be controlled. The following illustration shows the principle of operation of an MCP.

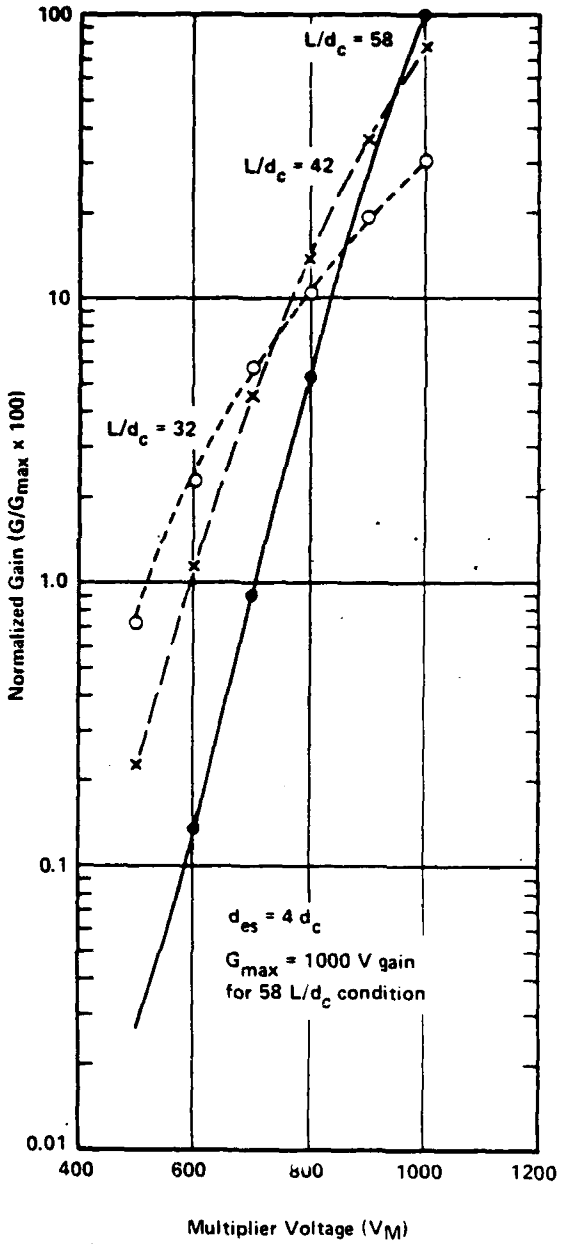


2

TYPICAL CHARACTERISTICS

The performance characteristics of a device such as the microchannel plate obviously depend on a complex interaction of its several electrical parameters with its physical parameters. Fortunately, these parameters can be manipulated to obtain certain desired performance effects. Prospective MCP users are encouraged to discuss their particular requirements in the application of MCP's with Varian's technical staff.

A discussion of MCP characteristics follows:



BIAS

In an MCP, the channels (or holes) are at a bias with respect to the parallel input and output surfaces. Typical values of this bias angle are 5^o and 8^o with respect to the plate surfaces. The intent of this bias angle is to:

- reduce ion feedback
- Increase the probability of impact of the incoming energy with the channel surface
- reduce direct light feedback from output phosphor screens

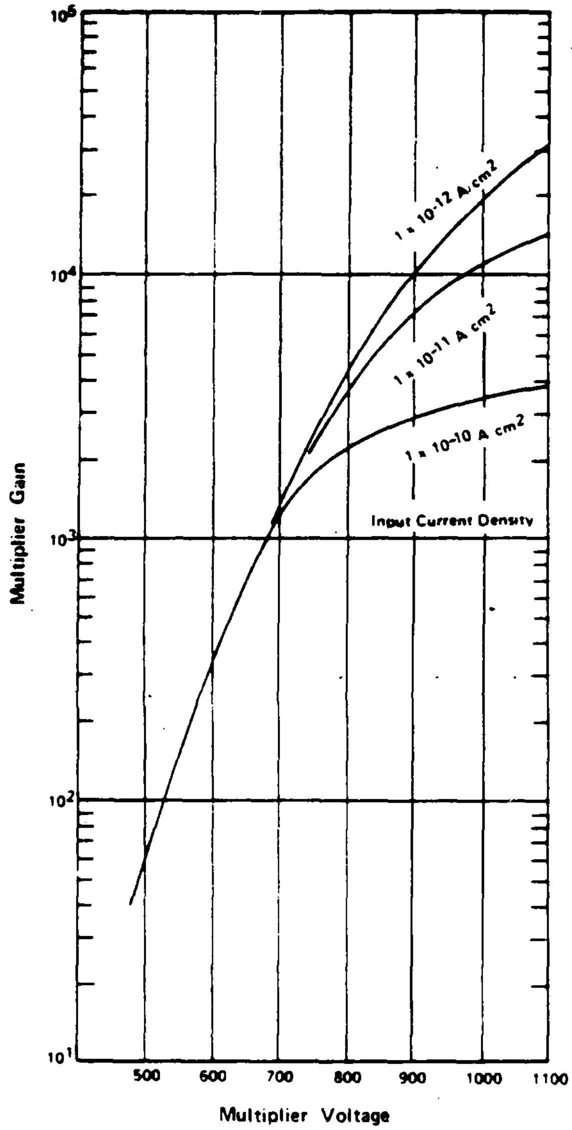
THICKNESS

The thickness of the MCP is dependent upon the channel hole size, and is usually designed for the particular user application. Typically, the L/d_c of the channels is in the range of 35 to 55 depending upon the end parameters (i.e. gain and uniformity) desired. For an L/d_c of 50, the VUW-8900 series MCP thickness is approximately 0.023 inch.

OPEN-AREA-RATIO

The Open-Area-Ratio (OAR) of the MCP is defined as the ratio of the open area to the total area of the MCP. Typically, the OAR of MCP's is greater than 50%.

GAIN

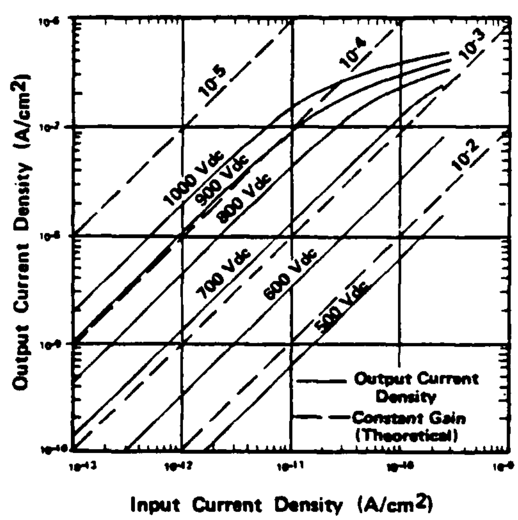


Typical Characteristics

L/d_c	=	42
d_c	=	14.5 μ
OAR	=	60 %
R	=	$3 \times 10^8\ \Omega$

The typical electron gain of the MCP is a function of the multiplier voltage and the input current density into the array. For example, in a VUW-8900 Series MCP, below 700 volts the multiplier gain is *independent of the input current density.* Above this voltage, the secondary electrons emerging from near the end of the channels raises the potential of the channel wall until there is a low field region which either maintains, but does not augment, the gain process, or actually acts as an electron sink (commonly referred to as gain saturation). This situation is analogous to that in a conventional photomultiplier when the output current from the last dynode exceeds the bleeder current in the resistor chain across the dynodes. In a microchannel plate, the output current is limited by the standing current along the walls of each channel, which is commonly referred to as the strip current of the multiplier. Therefore, as the resistance of the multiplier is decreased, the strip current in the multiplier increases and the saturation voltage increases. As a general rule of thumb, the gain of the multiplier array is linear up to the point where the output current density from the multiplier begins to exceed 5% of the strip current. A typical value for strip current in present state-of-the-art microchannel plates is approximately 1×10^{-6} A/cm^2 of active disc diameter.

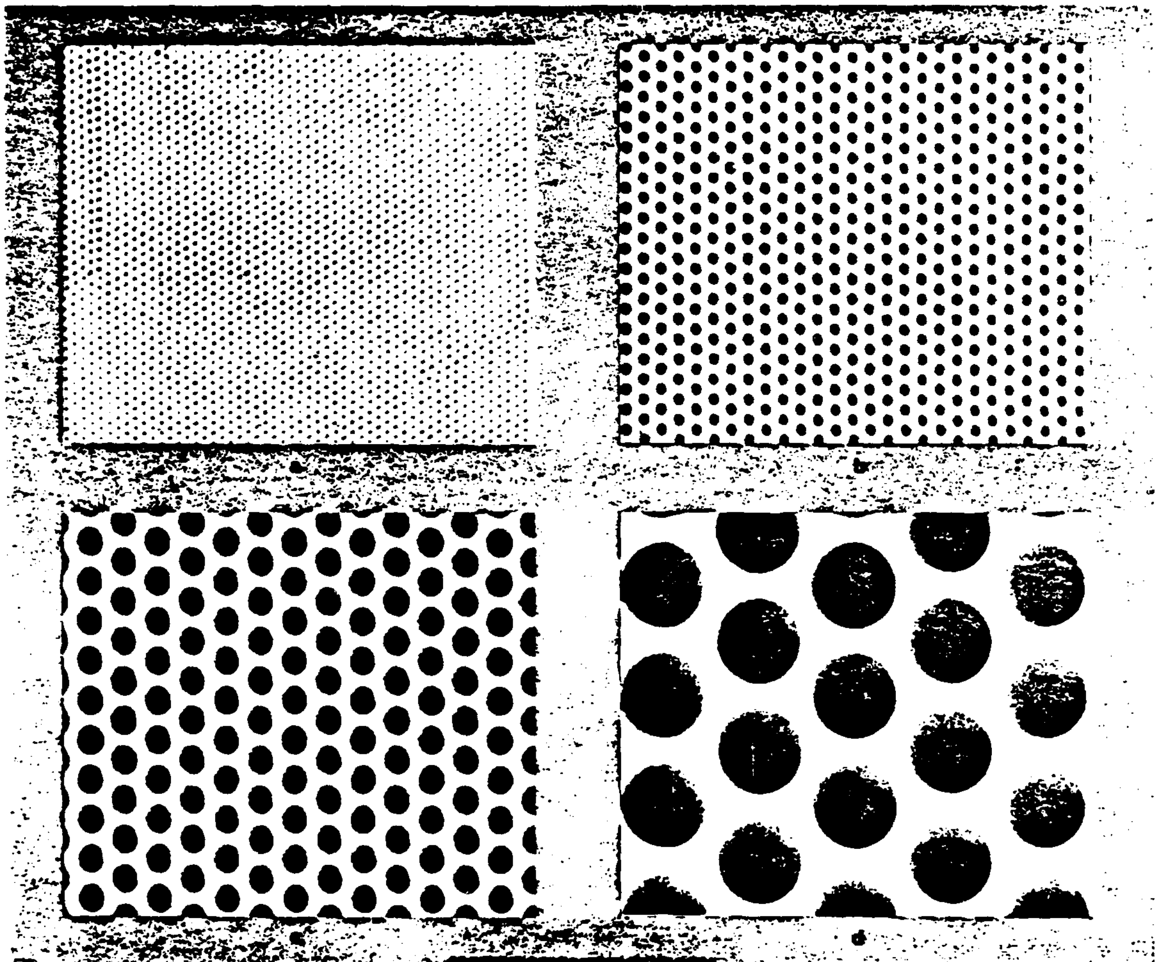
The limiting current characteristics of the MCP is normally seen by referring to the current transfer curves for the device. This self-saturating feature is one of the prominent advantages of the MCP in low level applications.



GAIN UNIFORMITY

Variation in the MCP gain as a function of the length-to-diameter ratio of the channels has been discussed. Since the multiplier array is an assembly of single channel multipliers fused together, variations in the channel diameters within the array will produce channel-to-channel gain variations which will appear as a spatial fixed pattern noise (FPN) in the output image.

Varian has achieved a virtual reduction of spatial noise over a wide operating gain region of the MCP through control of fabrication tolerances and optimization of the L/d_c of the multiplier. As the photomicrograph shows, channel-to-channel geometrical uniformities of ± 2% are achieved, which yield output gain uniformity of ± 5% over a gain range of 10 to 10,000.



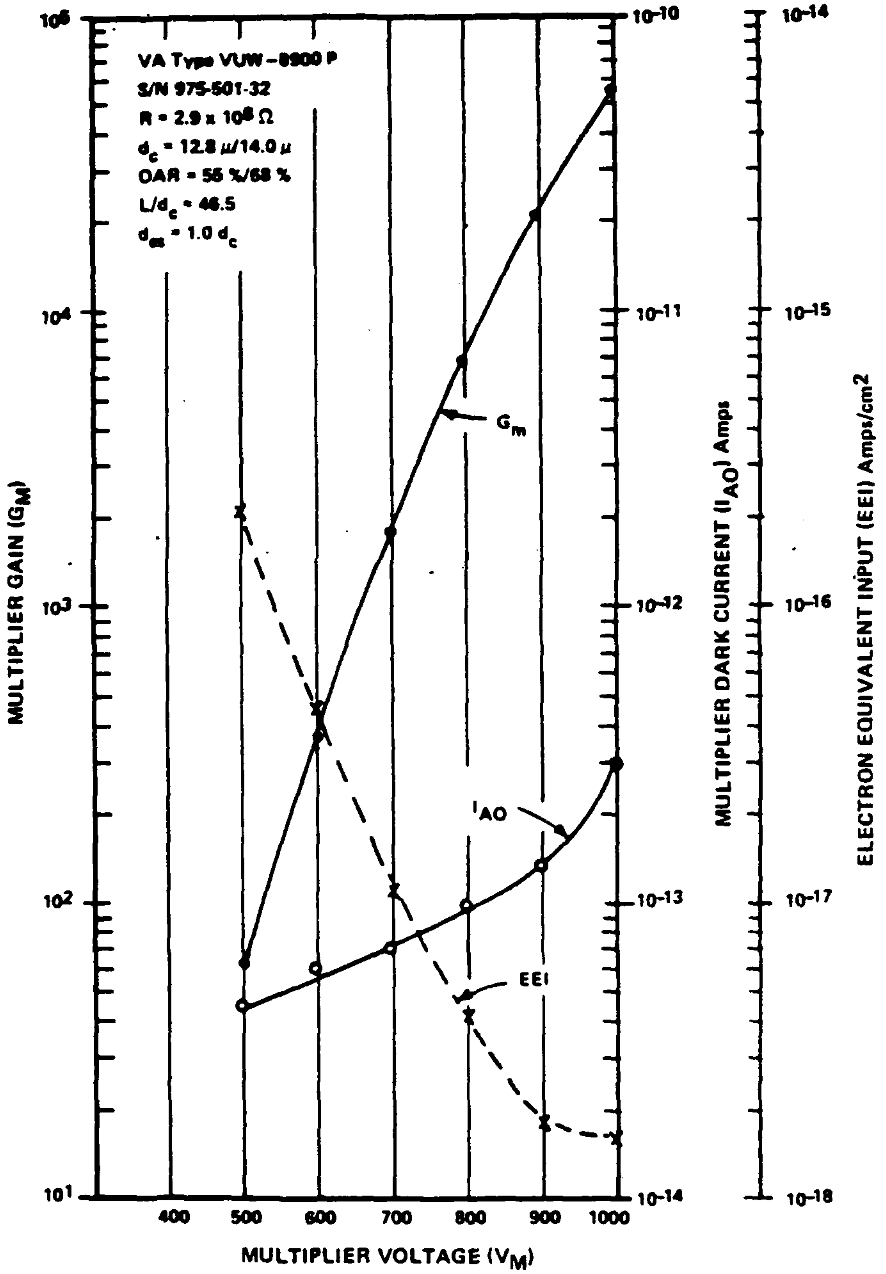
[illegible]

Center to Center Channel Spacing = [illegible] Microns; Channel Size = 14.6 Microns; Open Area Ratio = [illegible]; Approximate Magnification a) 40X, b) 80X, c) [illegible], d) 425X.

At higher input current density conditions ($>1 \times 10^{-10}$ A/cm^2), a slight "chicken wire effect" begins to appear. This effect is primarily noticeable when the microchannel plate is operated in the saturated gain region. As the multiplier resistance is decreased, the operating point for the appearance of "chicken wire" increases.

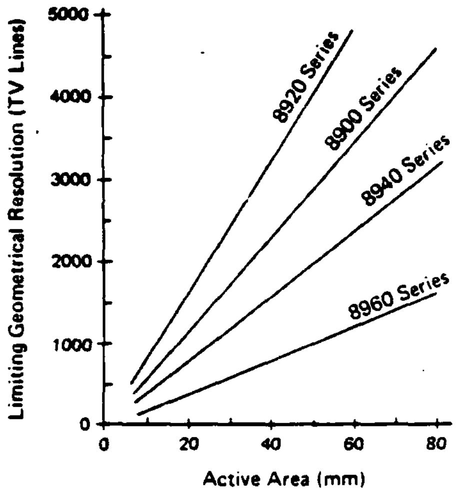
NOISE

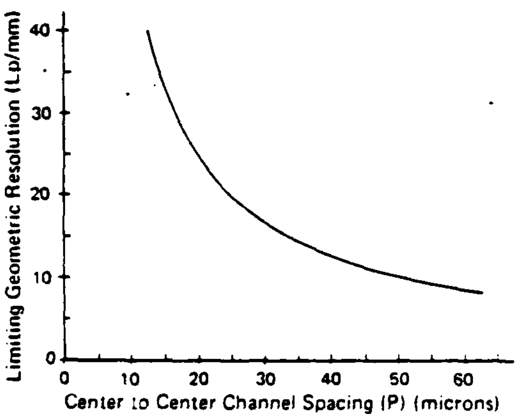
The noise characteristics of the MCP normally referred to are: multiplier dark current, I_{AO}; and equivalent electron input, EEI. The multiplier dark current is the output current derived from the MCP when the multiplier voltage is applied in the absence of an input electron signal. The equivalent electron input is the ratio of the multiplier dark current density to the multiplier gain at a constant multiplier voltage.



RESOLUTION

The basic limitation to resolution obtainable from microchannel plates (at high input levels), is the center-to-center channel spacing. Generally, for an **hexagonal close-pack** channel structure with center-to-center channel spacing p, the resolution limit is given by 1/2 p.

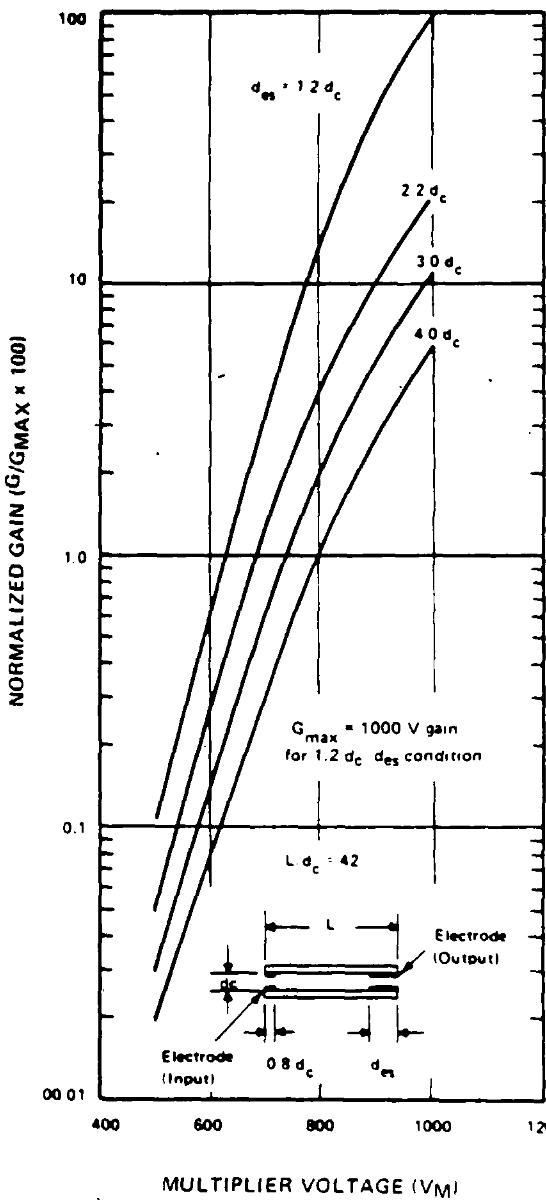




In many microchannel plate image intensifier applications, the phosphor viewing screen is placed in close proximity to the output of the microchannel plate. The resolution attainable is then a function of the electric field applied across this proximity spacing, and the center-to-center channel spacing. A technique commonly used to increase the resolution capabilities of the proximity output section is termed "end spoiling" of the output electrode. End spoiling refers to the penetration of the output electrode into the channels of the multiplier array in order to collimate the output electron beam. The end spoiling depth (d_{es}) is denoted in terms of channel diameters (d_c). End spoiling affects the overall gain of the multiplier.

Therefore, optimization between end spoiling depth, center-to-center channel spacing, and gain, must be realized with regards to resolution requirements. Optimum compromise is in the range of 1.0 d_c to 2.0 d_c.

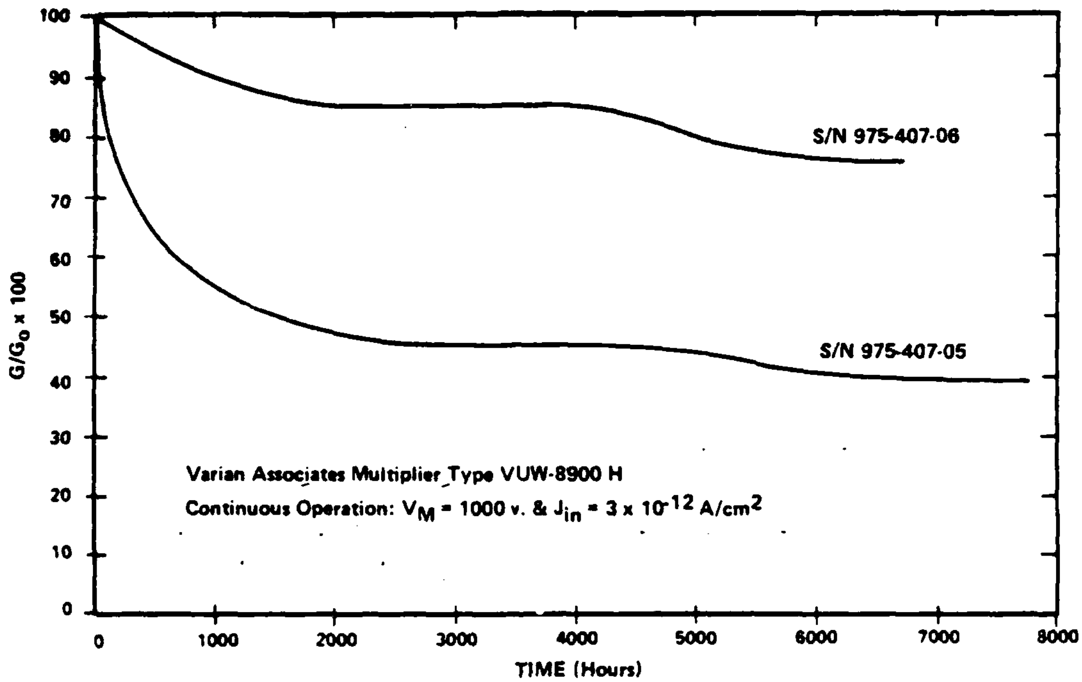
In order to increase the probability that the first impact of incident radiation occurs on the inner glass surface, and not on the input electrode, the input electrode penetration is usually controlled to 0.5 d_c to 0.8 d_c.



7

OPERATIONAL LIFE

Microchannel plates have been continuously operated up to 7800 hours. The previous processing history of the MCP is an important factor in its life characteristics. Extreme cleanliness is required in the handling and processing of MCP's. The differences in the life characteristics of the two MCP's shown can be attributed to preprocessing history.

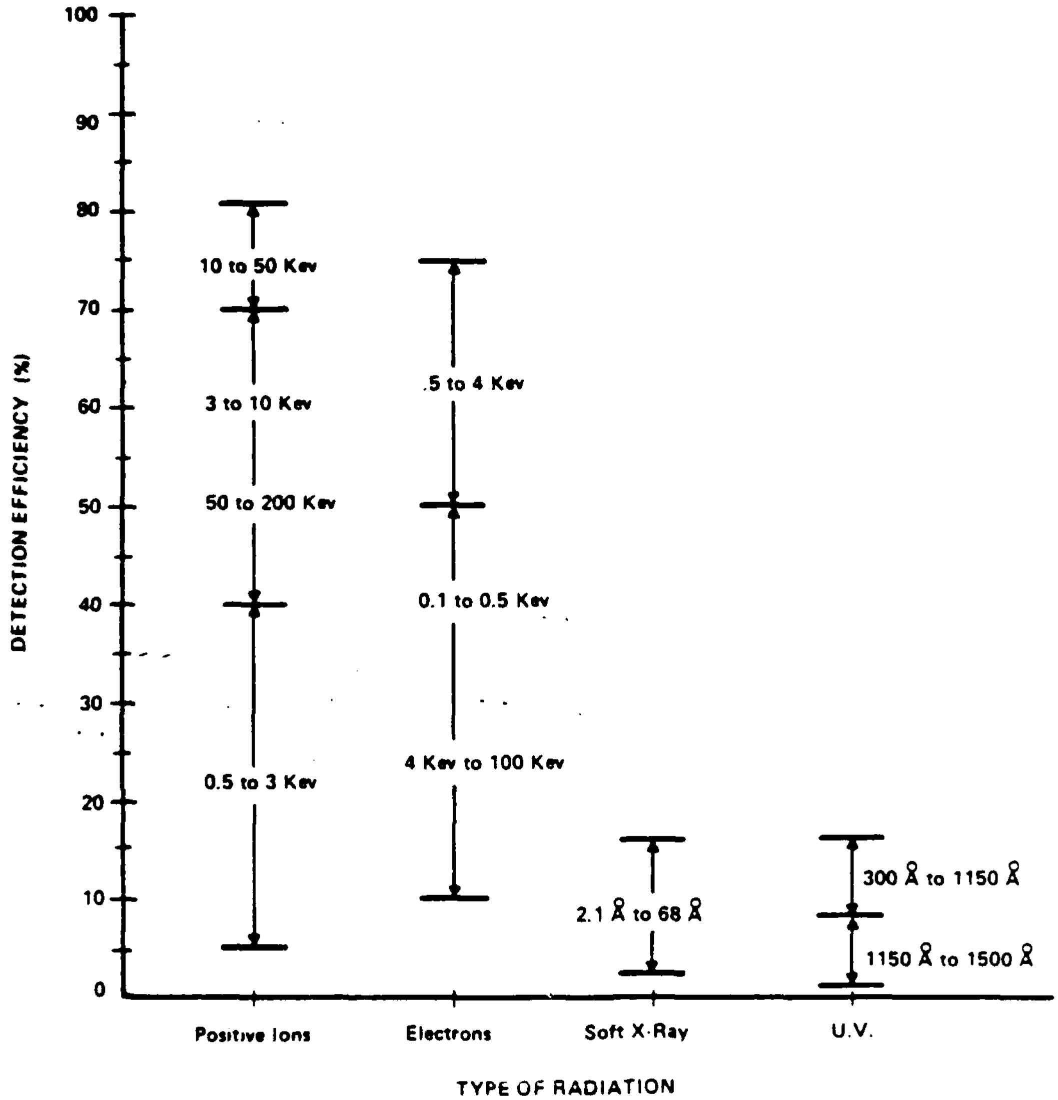


	975-407-05	975-407-06
G_o	7.4×10^3	4.4×10^3
R	$2.6 \times 10^8\ \Omega$	$3.1 \times 10^8\ \Omega$
d_c	14.6 μ	14.6 μ
L/d_c	43.5	42.6
OAR	58%	58%
d_{es}	3 d_c	3 d_c

DETECTION EFFICIENCY

The MCP is sensitive to many types of radiation. The detection efficiency is defined as the percentage of input particles or quanta producing detectable pulses at the multiplier output. A chart of the detection efficiency of the MCP to various types of radiation in various energy ranges is given.

DETECTION EFFICIENCY



TRANSIT TIME

The electron transit times through the MCP are less than 1 nanosecond with a transit time spread of approximately 0.1 nanosecond. Therefore, the MCP is ideally suitable for applications where detection of high speed phenomena/events is required.

APPLICATIONS

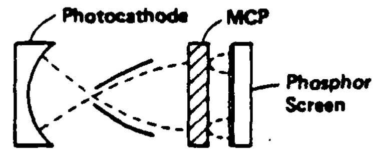
The MCP can be operated as a single plate multiplier, or in a tandem-dual plate operation.

The single plate mode of operation is used primarily in the following applications:

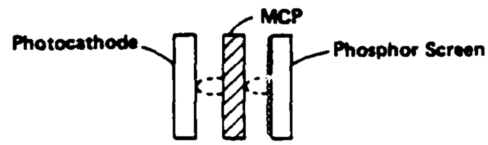
- **Image intensifiers (various types)**
- **Camera tubes**
- **Cathode ray tubes**

Where detection of quantum events is required, the tandem arrangement of channel multiplier plates is used. In this application, two microchannel plates are placed in close proximity (approximately 1 mil separation) with their bias angles opposing (opposing bias angles is used to reduce ion feedback effects). In this configuration, electron gains in excess of 10^7 can be achieved. Typical output noise dark counts which have been routinely achieved in this configuration are 1.1 to 1.7 counts/sec/cm^2, over an operating voltage range of 1600 to 2200 volts.

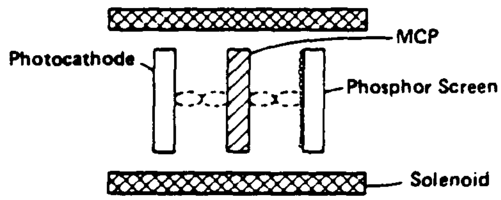
IMAGE TUBE APPLICATIONS



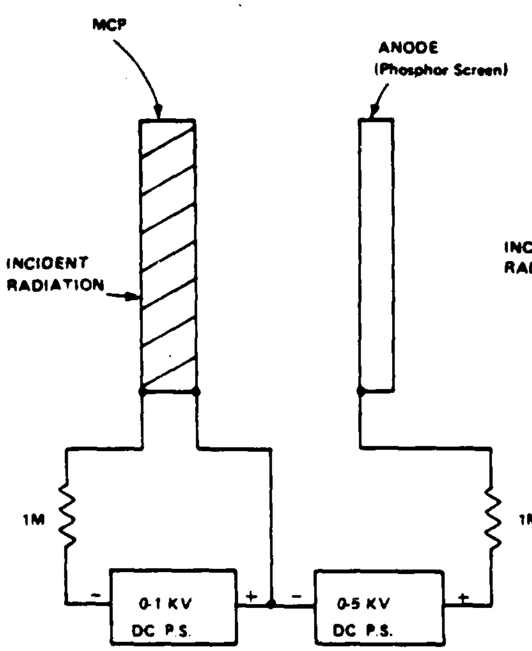
ELECTROSTATIC FOCUS IMAGE INTENSIFIER



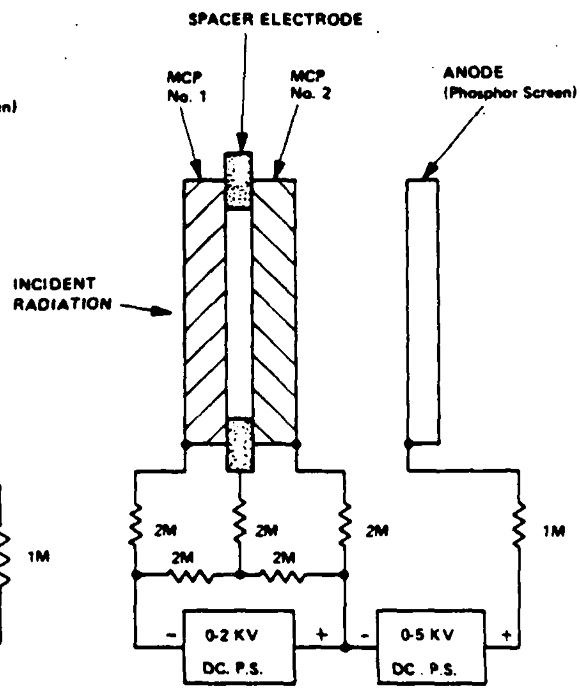
PROXIMITY FOCUS IMAGE INTENSIFIER



ELECTROSTATIC & MAGNETIC FOCUS IMAGE INTENSIFIER



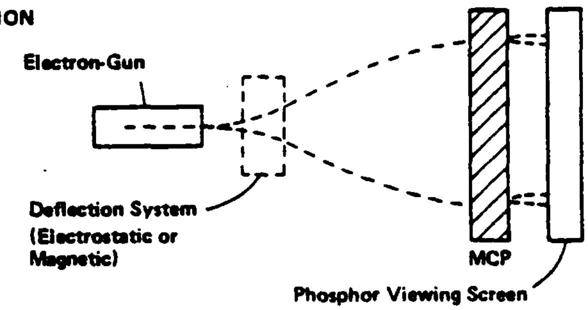
SINGLE PLATE OPERATION



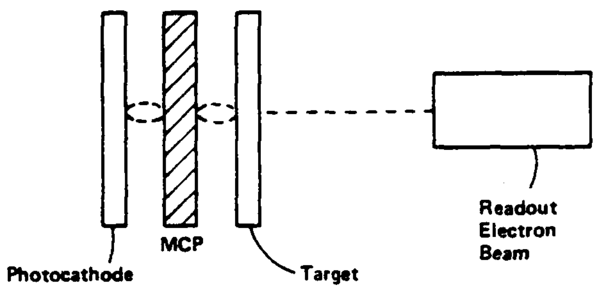
TANDEM—DUAL PLATE OPERATION

10

CRT APPLICATION



CAMERA TUBE APPLICATION



AVAILABLE TYPES

Microchannel plates are classified in accordance with their channel to channel spacing (pitch), and imaging active area plate overall diameter, as follows:

		Center-to-Center Channel Spacing, pitch (microns)		
Useful Imaging Area (mm)	Plate Diameter (in)	12.5	15	50
18	.975	VUW-8921	VUW-8900	–
25	1.287	8922	8911	–
25	1.410	–	–	VUW-8964
40	1.970	–	8908	8968

All types except for the 40mm useful imaging area MCP's have solid glass borders from the active area to the plate outside diameter.

The VUW-8920 series MCP's are considered the high resolution type, in contrast to the medium resolution VUW-8900 series and low resolution VUW-8940 series.

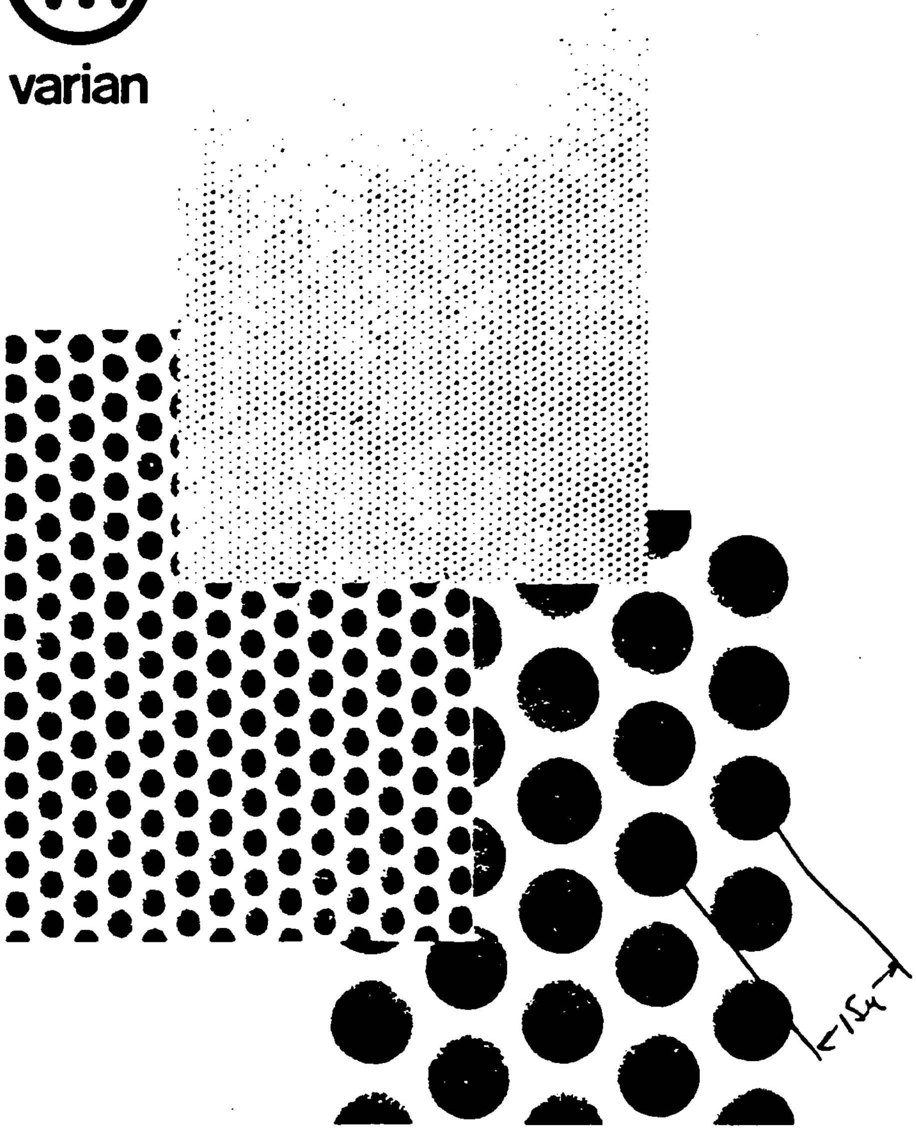
The primary application of the 8960 series is in spatial quantuum detectors and or amplifiers.

The above information by no means covers the capabilities available. We welcome inquiries with regards to other variations to the customer specifications.

GLOSSARY OF TERMS – MICROCHANNEL PLATES

PARAMETER	UNITS	SYMBOL	DEFINITION
Input Surface:	–	–	Surface of channel electron multiplier with largest geometrical electrode pattern. (Noted on VA Type Drawings)
Output Surface:	–	–	Surface of channel electron multiplier with smaller geometrical electrode pattern. (Noted on VA Type Drawings)
Channel Diameter:	microns	d_c	The diameter of the individual channels (holes) in the microchannel plate.
Channel Pitch:	microns	P	The center-to-center channel spacing.
Bias Angle:	degrees	α	Angle formed by the axis of the channel and the normal to the plate surfaces.
End Spoiling:	d_c	d_{es}	Depth of penetration of the output electrode into the individual channels
Open Area Ratio:	%	OAR	The ratio of open area of the multiplier to the total area of the multiplier. $OAR = .907 \left(\frac{d_c}{p}\right)^2$
Disc Diameter:	inches	D	Outside diameter of the Channel Multiplier Array.
Useful Area:	mm	A_A	The area of the array which is available for useful imaging. NOTE: This area is highly dependent upon individual users final tube mounting assembly design.
Length to Diameter Ratio:	–	L/d_c	Ratio of the thickness of the multiplier to the hole diameter of the channels
Electrode Area:	cm^2	A_E	Area of the output electrode surface.
Multiplier Voltage:	volts	V_M	Voltage applied between the input and output surfaces of the multiplier. Positive polarity on output.
Strip Current:	amps	I_S	Current that flows through multiplier when multiplier voltage is applied in the absence of input electron signal.
Operating Current:	amps	I_{OP}	Current that flows through multiplier when multiplier voltage is applied and input electron signal is applied.
Multiplier Resistance:	ohms	R	Ratio of multiplier voltage to strip current: $R = \frac{V_M}{I_S}$ (ohms)
Multiplier Resistivity:	ohms-cm^2	ρ	Product of electrode area and the multiplier resistance, i.e., the resistance of a one square cm. multiplier $\rho = A_E \quad R$ (ohms-cm^2)
Multiplier Output Current:	amps	I_A	Output current derived from multiplier when multiplier voltage and signal current is applied.
Multiplier Input Current:	amps	I_{in}	Input current signal presented to the input surface of the multiplier
Multiplier Dark Current:	amps	I_{AO}	Output current derived from multiplier when multiplier voltage is applied and in the absence of an input electron signal
Multiplier Dark Current Density:	$\frac{amps}{cm^2}$	J_{AO}	Ratio of the multiplier dark current to electrode area $J_{AO} = \frac{I_{AO}}{A_E}$
Equivalent Electron Input:	$\frac{amps}{cm^2}$	EEI	Ratio of the multiplier dark current density to the multiplier gain at a constant multiplier voltage $EEI = \frac{J_{AO}}{G}$
Multiplier Gain:	–	G_M	Current gain of the multiplier, i.e. Ratio of the multiplier output current minus the dark current to the multiplier input current $G_M = \frac{I_A - I_{AO}}{I_{in}}$ When the input and output areas differ, the multiplier gain becomes the ratio of the current densities $G_M = \frac{J_A - J_{AO}}{J_{in}}$
Fixed Pattern Noise:	–	FPN	Spatial gain nonuniformity caused by geometrical channel to channel variations
Chicken Wire:	–	–	Hexagonal dark screening effect caused by gain nonuniformities when the MCP is operated in saturation

varian



LIGHT SENSING AND EMITTING DIVISION/611 Hansen Way, Palo Alto, California 94303/Telephone: (415) 493-4000

MCP-2819B (Printed in U.S.A.) 1175

DISTRIBUTION FOR REPORT NO. 0064

Center for Night Vision and Electro-Optics

6 AMSEL-RD-NV-D
1 AMSEL-RD-NV-D-CS
2 AMSEL-RD-NV-PA/ILS
12 AMSEL-RD-NV-TS
1 AMSEL-RD-NV-IT
1 AMSEL-RD-NV-TS-SOT
1 AMSEL-RD-NV-V
1 AMCPEO-IEW-NVD

Department of the Army

Commander, TRADOC
1 ATTN: ATCD-ML
1 ATTN: ATCD-TE
Fort Monroe, VA 23551-5000

Headquarters, Department of the Army
Program Executive Officer
Intelligence Electronic Warfare
Vint Hill Farm Station
Warrenton, VA 22186-5115

Commander, CECOM
1 ATTN: AMSEL-TDD
1 ATTN: DELSD-L
1 AMSEL-ME-PSL
Fort Monmouth, NJ 07703-5001

Commander, AMC
ATTN: AMCSM-NC
5001 Eisenhower Avenue
Alexandria, VA 22333

Defense Technical Information Center
ATTN: DTIC-FDA
Cameron Station, Bldg 5
Alexandria, VA 22304-6145

Commander, US Army Materiel Readiness
Support
Activity
ATTN: AMXD-ED
Lexington Bluegrass Depot
Lexington, KY 04511-5101

Commander, Sacramento Army Depot
ATTN: SDSSA-MSD-3
Sacramento, CA 95813-5000

Commander, US Army Signal Center
and Fort Gordon
1 ATTN: ATZH-CDL
1 ATTN: ATZH-DTN
Fort Gordon, GA 30905

Commander, US Army Systems Analysis
Agency
1 ATTN: AMXSY-CS
1 ATTN: AMSTE-EV-R
1 ATTN: AMSTE-EV-S
1 ATTN: AMSTE-TE-T
Aberdeen Proving Ground, MD 21005